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AVIATION NIGHT VISION GOGGLE

FINAL TECHNICAL REPORT

13 JULY 1977 TO 16 MARCH 1979

CONTRACT NO: DAAK70 - 77 - C 0179

PREPARED FOR:

MERADCOM

PROCUREMENT AND PRODUCTION DIRECTORATE

FORT BELVOIR, VIRGINIA 22060

PREPARED BY:

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ITT *Electro-Optical Products Division*

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The intent of this program was to demonstrate the feasibility of a light-weight goggle which possessed a unique "flip-up" capability and utilized the existing Generation II or (Gen III) lightweight image intensifier assembly. The contract originally extended over a period of 14 months, starting in July, 1977 and terminating August, 1978. Modification to the contract extended the program to October, 1978.

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The contract consisted of the design, fabrication, test, and delivery of two Aviation Goggles with two minor design iterations. The contract modification consisted of retrofitting two sets of goggles with lightweight image intensifier tubes.

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ABSTRACT

This Final Report for contract number DAAK70-77-C-0179, including modification P00002, is submitted in compliance with line item 0002 of DD Form 1423 dated 30 June 1977. The report contains all test data obtained from the two prototypes which were delivered. In addition, this document includes complete test data on the two design modifications.

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1.0 INTRODUCTION AND SUMMARY

1.1 General

This Final Technical Report for contract number DAAK70-77-C-0179 summarizes the efforts to develop a light-weight, night vision goggle using plastic lenses, power supplies, and image intensifier assemblies of reduced weight.

The objective of the program was twofold: (a) to build an experimental model of a lightweight goggle which possessed a unique "flip-up" capability and utilized a Generation II image intensifier assembly and (b) to incorporate state-of-the-art designs to save weight and simplify construction.

The required goggles were developed and shipped to Night Vision Laboratories (NVL) for evaluation. Based on recommendations from NVL, the goggles were modified (Mod I) and returned to NVL for a second evaluation. In accordance with the recommendations evolving from their second evaluation, the goggles were again modified (Mod II) and returned.

The design approach was to simplify the goggle as much as possible to save weight and to incorporate new design innovations. To reduce the goggle moment, weight had to be removed from the monocular assembly. This was accomplished in the following manner:

a. The tube housing was made from plastic

b. Plastic lenses were incorporated

c. The image intensifier booth housing was eliminated

d. The wraparound power supply on the image intensifier was eliminated

e. Potting weight was reduced by mixing microballoons with the potting compound

f. The weight of the image intensifier was reduced

g. The diopter ring adjustment and inter-pupillary adjustment was simplified

The wraparound power supplies were replaced with a single, external power supply that could be mounted on the flight helmet or placed in the user's pocket. This power supply provided power to both avionics tubes simultaneously and possessed both bright source protection and automatic brightness control. Since the power supply was externally

mounted, high voltage cables were developed to prevent any voltage drop, dielectric leakage, or current drain during transition of power to the goggles. The high voltage cables met all Military Standard requirements for vibration, shock, temperature cycling, and resistance to corrosion and moisture.

High voltage connectors were developed to make the monocular assembly field replaceable. These connectors were designed to prevent any voltage drop, dielectric leakage, or current drain and to meet all environmental specifications. In addition, the weight of the image intensifier tube was reduced by replacing the fiber-optic faceplate with a 0.060" glass window faceplate.

To simplify the diopter adjustment, the adjustment ring was eliminated and the eyepiece barrel was knurled for a better grip while adjusting the diopter. Although the objective lens was designed to be fixed at infinity, fine threads were machined on the objective lens barrel if adjustment was required. Also, interpupillary adjustment was simplified through independent monocular assemblies which were secured into position by a screw.

The face mask was designed to provide the wearer peripheral vision with the goggles in either position (i.e., up or down). The mask consisted of two sections: one section of the mask remained fixed to the face at all times, while the other section (which supported the binocular assembly) could be flipped up when the goggle was not being used. The goggles could either be mounted to the head or directly to the flight helmet through the use of a special head strap.

The power pack was designed to house the push button ON - OFF switch, 28-Vdc aircraft power adapter, 9-Vdc battery, image intensifier supply, 28-Vdc cable with breakaway capability, and high voltage connectors.

1.2 Mod I Goggles

The required goggles were developed and shipped to Night Vision Laboratories (NVL) for evaluation. Based on recommendations from NVL, the goggles were modified (Mod I) and returned to NVL for a second evaluation. Table 1-1 summarizes the pilot's comments and the resultant design modifications incorporated into the Mod I goggles.

Table 1-1. Mod I Goggles.

	Pilots' Flight Evaluations	Design Modifications Incorporated
Head Strap	Insufficient strap adjustment; no apparent way to preposition and hold harness in place while attaching system; second person needed to secure on unit	Replaced universal head strap with standard AN/PVS-5 avionics head strap, thus simplifying design and saving weight
Interpupillary Adjustment	Adjustment required screw driver to loosen four screws, position each tube independently, and tighten screw; screws inaccessible and located near high voltage cables; any movement of tube location during tightening necessitated repeating procedure; procedure too time consuming	Redesigned glass cathode tube housing changing screw holes from vertical to horizontal position, making adjustment easier and preventing wear on high voltage cable
Fore/Aft and Tilt Adjustments	Insufficient range to accommodate	Added more adjustment range resulting in increased mask length; eliminated ears; removed additional side material for better vision; added step to mask to prevent wear to high voltage cable
Off/On Switch	No off/on position indicator; can be inadvertently pushed	Replaced switch with a standard AN/PVS-5 switch marked ON/OFF

Table 1-1. Mod I Goggles (continued).

	Pilots' Flight Evaluations	Design Modifications Incorporated
Goggles	Insufficient tilt back in up position; forward vision blocked	Eliminated springs on hinges and added velcro tab on end of face mask and on end of avionics "V" straps; system placed up out of line of sight
Wings	Hazardous on flip-up portion; limit forward vision	---
Diopter Adjustment	Too stiff; not accessible in down position; loosens by turning all the way in	Redesigned mask made adjustment more accessible; fine pitch thread machined over multiple thread and stop ring screwed into position to prevent eyepiece lens from coming out
High Voltage Connectors	Connection at housing appears susceptible to wear during flip-up/flip-down	Eliminated connectors to save weight; used pin connections to mate with power supply for ease of installation
High Voltage Power Cables	Not included in pilots' evaluation	Repackaged in conductive heat shrinkable tubing, saving weight, providing smaller package and achieving better RFI shielding

Table 1-1. Mod I Goggles (continued).

	Pilots' Flight Evaluations	Design Modifications Incorporated
Total Helmet - Goggle Center of Gravity	Exceptionally good	No modification necessary
Wide Open Design	Very good	No modification necessary
Flip-up/Flip-down	Good; better if goggles rotated 20° to 30° more	---
Peripheral Vision	Good below the goggle tubes	No modification necessary
Surgical Foam Face Cushion	Good	No modification necessary
Brown Eye Syndrome	None experienced with open design	No modification necessary
Fatigue	Very low	No modification necessary

1.3 Mod II Goggles

The Mod I goggles were subjected to a second flight evaluation at NVL. A summary of the pilot's comments follows:

a. A radio frequency interference problem occurred when the 28-Vdc line mated with aircraft power

b. The flip-up feature provided a much improved swing distance

c. The lock-up position would not secure the binocular assembly because reverse tension was caused by the goggle's V-mounting strap and tube wires

d. Major improvements have been made in the adjustment mechanisms, interpupillary adjustment, and diopter adjustment

e. No undesirable vibrations were encountered during hovering, bob-up, and nap-of-the-earth maneuvers

f. No EMI problems occurred with battery power

g. The goggle weight distribution was very good

h. The ON/OFF switch should be placed on the left side of the power supply rather than on top

i. The goggle power pack fitted comfortably on the pilot's forehead

j. All adjustment straps were easily accessible and provided a snug fit

k. Peripheral vision was fair

1. The weight and weight distribution was very comfortable. Pilot fatigue would set in as a result of eye strain from peering through the tubes before the weight of the goggle would become a factor

Based on this evaluation, the goggles were again modified (Mod II, see Table 1-2) and returned. Table 1-3 summarizes all three configurations.

1.4 Requirements

The requirements for the experimental prototype Aviation Night Vision Goggle are shown in Table 1-4. Each requirement was considered during the design stage. Top priority was given to weight, center of gravity of the helmet, performance, and the flip-up feature.

1.5 Performance

The performance of the experimental prototype Aviation goggle was measured by comparing the prototype with the capabilities of the AN/PVS-5 goggles. The results of this comparison are shown in Table 1-5. The specification requirements for target brightness and brightness gain are shown in parentheses.

Table 1-2. Design Modifications Incorporated Into Mod II Goggles.

- One set of goggles was modified to incorporate the K&M Avionics power supply
- Generation II, high performance image intensifier assemblies were incorporated into both sets of goggles
- The tube housing in both sets of goggles was redesigned to accommodate the increased length due to the fiber-optic faceplate
- Microminiature connectors and cables were used in the goggle system which incorporated the K&M power supply
- The locking mechanism was changed to a spring plunger type to secure the mask in either position (this change was made in both systems)
- Lever arms were added to both systems for easier diopter adjustment
- More material was trimmed off of the face mask to provide better peripheral vision in both systems

Table 1-3. Design Configurations for Aviation Goggles

Component	First Delivery	Mod I	Mod II
Image Intensifier Tube - 18 mm	Gen II wafer type intensifier tube. S-20 photocathode with extended red response. Tube assembly used micro-channel-electron-multiplier plate with proximity focus on input and output. Assembly contained 0.060" glass window input faceplate and a fiber-optic inverter as an integral part of the tube envelope.	Same tubes as first delivery except tube housing changed.	High resolution, Gen II, Avionics tube with RCA F2126, Type 10-52 phosphor screen. The assembly contained fiber-optic input faceplate and a fiber-optic inverter as an integral part of the tube envelope

Table 1-3. Design Configurations for Aviation Goggles (continued).

Component	First Delivery	Mod I	Mod II
Power Supply	External single supply provides power to both image intensifier tubes	Same as first delivery except for the elimination of high voltage connectors and modification to the high voltage cables.	One pair of goggles had same power supply as Mod I. After evaluation this supply was re-placed in the second pair of goggles by two internally mounted, K & M donut power supplies which provided power to tubes on an individual basis.

Table 1-3. Design Configurations for Aviation Goggles (continued).

Component	First Delivery	Mod I	Mod II
High Voltage Cables	Cables mated with external power supply and tube assembly.	High voltage cables less connectors.	One design had H. V. cables; in other design, H. V. cables eliminated.
High Voltage Connectors	High voltage connectors provide an interface between high voltage cables and power supply.	Eliminated from design.	One design, same as Mod I; in other design, microminiature connectors used.
Face Mask	Flip-up feature utilizing spring loaded hinges	Flip-up locking mechanism was changed to a Velcro® tab for securing in "up" position. A ball detent device was used to lock the mask in the "down" position.	Locking mechanism was changed to a spring plunger device for locking mask in either up or down position.

Table 1-3. Design Configurations for Aviation Goggles (continued).

Component	First Delivery	Mod I	Mod II
Binocular Assembly	Simplified design which included screws to lock interpupillary adjustment.	Modification included new tube housing, eyepiece adapter sleeves, thumb screws, wing screws, etc.	Total binocular assy was changed from Mod I design. Change included tube housing, thumb screws, etc.
Head Strap	Universal head strap which could either be placed over the helmet or adjusted to uncovered head (if goggles were worn without helmet)	Modified back to standard AN/PVS-5 straps	Same as Mod I
Face Cushion	Made from surgical foam with Velcro® backing	Additional foam cushions (of various densities) were supplied	Modified standard AN/PVS-5 cushions

Table 1-3. Design Configurations for Aviation Goggles (continued).

Component	First Delivery	Mod I	Mod II
Demist Shield	Demist shield screwed into eyepiece housings	Eliminated because mask had such good ventilation without using shields	Same as Mod II

Table 1-4. Requirements for Experimental Prototype Aviation Goggle.

Parameter	Requirement
Weight	Face mask assy = 580 g Power pack = 200 g
Center of gravity	To be measured
Environmental conditions	Design goals
Controls and adjustments	Interpupillary, diopter focus, on and off
Resolution	50 line pairs/miliradian
Field of view	40°
Magnification	Unity
Objective lens	Focal length = 25 mm
Eyepiece lens	Focal length = 26 mm Exit pupil = 8 mm Eye relief = 15 mm

Table 1-5. Aviation Goggle Performance.

SYSTEM TEST

SERNO 001

MOD NA

RESOLUTION

Chart number resolved 3:3 left 3:1 right (unaided eye)

System resolution 10.1 lp/mm 8.0 lp/mm

Close focus 4.75 inches

COLLIMATION

Collimation with 1^{o} divergence/convergence OK

Collimation with $1/2^{o}$ divergence OK

FOCUS RANGE	Left	Right
Resolution at infinity	30.5+lp/mm	30.5+lp/mm
Tube resolution (tube test data)	36 lp/mm	36 lp/mm
Diopter adjust	>+4 >-5 diopt	>+4 >-5 diopt

BRIGHTNESS GAIN	Left	Right
Target brightness (5×10^{-4} fL)	5×10^{-4} fL	5×10^{-4} fL
ANVG output brightness	.5 fL	.35 fL
ANVG brightness gain (Gs 320 fL/fL	1000 fL/fL	700 fL/fL

RISE TIME

Left <1 seconds

Right <1 seconds

BRIGHTNESS MATCH

Brightness match OK

INTERPUPILLARY ADJUSTMENT

Minimum distance 40.5 mm

Maximum distance 92 mm

WEIGHT

Face mask 440 g

Power pack 256.7g

Straps 130.3g

MOMENT

M_1 = 0

Table 1-5. Aviation Goggle Performance (continued).

SYSTEM TEST

SERNO 002

MOD NA

RESOLUTION

Chart number resolved 3:3 left 3:3 right (unaided eye)
System resolution 10.1 lp/mm 10.1 lp/mm
Close focus 4.75 inches

COLLIMATION

Collimation with 1° divergence/convergence OK
Collimation with $1/2^{\circ}$ divergence OK

FOCUS RANGE	Left	Right
Resolution at infinity	27 lp/mm	30.5 lp/mm
Tube resolution (tube test data)	36 lp/mm	36 lp/mm
Diopter adjust	>+4 >-5 diopt	>+4 >-5 diopt

BRIGHTNESS GAIN	Left	Right
Target brightness (5×10^{-4} fL)	5×10^{-4} fL	5×10^{-4} fL
ANVG output brightness	.19 fL	.16 fL
ANVG brightness gain (Gs 320 fL/fL	380 fL/fL	320 fL/fL

RISE TIME

Left <1 seconds
Right <1 seconds

BRIGHTNESS MATCH

Brightness match OK

INTERPUPILLARY ADJUSTMENT

Minimum distance 40 mm
Maximum distance 91 mm

WEIGHT

Face mask 440 g
Power pack 256.7g
Straps 130.3g

MOMENT

$M_1 =$ 0

Table 1-5. Aviation Goggle Performance (continued).

SYSTEM TEST

SERNO 001 A

MOD I

RESOLUTION

Chart number resolved 3:1 left 3:1 right (unaided eye)
System resolution 10.1 lp/mm 8.0 lp/mm
Close focus 4.75 inches

COLLIMATION

Collimation with 1° divergence/convergence OK
Collimation with 1/2° divergence OK

FOCUS RANGE	Left	Right
Resolution at infinity	30.5+ lp/mm	30.5+ lp/mm
Tube resolution (tube test data)	36 lp/mm	36 lp/mm
Diopter adjust	>+4 >-5 diopt	>+4 >-5 diopt

BRIGHTNESS GAIN	Left	Right
Target brightness (5 X 10^{-4} fL)	5 X 10^{-4} fL	5 X 10^{-4} fL
ANVG output brightness	.5 fL	.35 fL
ANVG brightness gain (Gs 320 fL/fL	1000 fL/fL	700 fL/fL

RISE TIME

Left <1 seconds
Right <1 seconds

BRIGHTNESS MATCH

Brightness match OK

INTERPUPILLARY ADJUSTMENT

Minimum distance 40.5 mm
Maximum distance 92 mm

WEIGHT

Face mask 383.8 g
Power pack 256.7 g
Straps 39.07 g

MOMENT

M_1 = 0

Table 1-5. Aviation Goggle Performance (continued).

SYSTEM TEST

SERNO 002 A

MOD I

RESOLUTION

Chart number resolved 3:3 left 3:3 right (unaided eye)

System resolution 10.1 lp/mm 10.1 lp/mm

Close focus 4.75 inches

COLLIMATION

Collimation with 1° divergence/convergence OK

Collimation with 1/2° divergence OK

FOCUS RANGE	Left	Right
Resolution at infinity	27 lp/mm	30.5 lp/mm
Tube resolution (tube test data)	36 lp/mm	36 lp/mm
Diopter adjust	>+4 >-5 diopt	>+4 >-5 diopt

BRIGHTNESS GAIN	Left	Right
Target brightness (5×10^{-4} fL)	5×10^{-4} fL	5×10^{-4} fL
ANVG output brightness	.19 fL	.16 fL
ANVG brightness gain (Gs 320 fL/fL	380 fL/fL	320 fL/fL

RISE TIME

Left <1 seconds

Right <1 seconds

BRIGHTNESS MATCH

Brightness match OK

INTERPUPILLARY ADJUSTMENT

Minimum distance 40 mm

Maximum distance 91 mm

WEIGHT

Face mask 383.8 g

Power pack 256.7 g

Straps 39.07 g

MOMENT

M_1 = 0

Table 1-5. Aviation Goggle Performance (continued).

SYSTEM TEST

SERNO 001 B

MOD II

RESOLUTION

Chart number resolved - left - right

System resolution 34.7 lp/mm 34.7 lp/mm

Close focus - inches

COLLIMATION

Collimation with 1° divergence/convergence OK

Collimation with $1/2^\circ$ divergence OK

FOCUS RANGE	Left	Right
Resolution at infinity	34.7 lp/mm	34.7 lp/mm
Tube resolution (tube test data)	37 lp/mm	37 lp/mm
Diopter adjust	>+4 -5.8 diopt	>+4 -6.3 diopt

BRIGHTNESS GAIN	Left	Right
Target brightness (5×10^{-4} fL)	4.95^{-4} fL	4.95^{-4} fL
ANVG output brightness	.35 fL	.5 fL
ANVG brightness gain (Gs 320 fL/fL	705 fL/fL	1010 fL/fL

RISE TIME

Left 5 seconds

Right 5 seconds

BRIGHTNESS MATCH

Brightness match OK

INTERPUPILLARY ADJUSTMENT

Minimum distance 39.5 mm

Maximum distance 89.5 mm

WEIGHT

Face mask 469.0 g

Power pack 214.5 g

Straps 39.07 g

MOMENT

M_1 = 0

Table 1-5. Aviation Goggle Performance (continued).

SYSTEM TEST

SERNO 002 B

MOD II

RESOLUTION

Chart number resolved - left - right

System resolution >26 lp/mm >26 lp/mm

Close focus - inches

COLLIMATION

Collimation with 1^{o} divergence/convergence OK

Collimation with $1/2^{o}$ divergence OK

FOCUS RANGE	Left	Right
Resolution at infinity	>26 lp/mm	>26 lp/mm
Tube resolution (tube test data)	37 lp/mm	36 lp/mm
Diopter adjust	>+4 -3.3 diopt	>+4 -4 diopt

BRIGHTNESS GAIN	Left	Right
Target brightness (5×10^{-4} fL)	5.4^{-4} fL	5.4^{-4} fL
ANVG output brightness	.24 fL	.22 fL
ANVG brightness gain (Gs 320 fL/fL	445 fL/fL	408 fL/fL

RISE TIME

Left 5 seconds

Right 5 seconds

BRIGHTNESS MATCH

Brightness match OK

INTERPUPILLARY ADJUSTMENT

Minimum distance 40 mm

Maximum distance 88.5 mm

WEIGHT

Face mask 461.57 g

Power pack 192.93 g

Straps 39.07 g

MOMENT

M_1 = 6.5 in.-lb

2.0 DESIGN DESCRIPTION

The design approach for the Aviation Night Vision Goggle was directed toward the development of a goggle which: (a) was as lightweight as possible, (b) reflected a weight distribution which resulted in the least possible moment forward of the center of gravity of the user's head, and (c) possessed optics and image tubes which could be moved out of the user's line of sight when desired. In addition, both the diopter adjustment rings and the interpupillary adjustment for the two tubes were to be simplified to save weight.

To obtain a better understanding of the weight distribution involved in the AN/PVS-5 goggles, a study was conducted of the weight of both components and assemblies. The results of that study are shown in Table 2-1.

2.1 Physical Design Description

The experimental model of the Aviation Night Vision Goggle served as a basis for further aviation goggle development efforts. The approach on the first experimental model was to develop a goggle which was both simplified and lightweight. After development, this model was subjected to

Table 2-1. Weight Distribution in AN/PVS-5 Goggles.

NIGHT VISION GOGGLES (SM-D-657300)

	Quantity		Weight (grams)
Binocular Assy (SM-D-657301)	1		645.01
Mask Assy, Face (SM-D-657400)	1		117.21
Cord Neck (SM-C-657303)	1		4.70
Cushion Assy, Face (SM-D-657302)	1		36.30
Knob Assy (SM-B-657370)	2		13.00
Battery	1		24.50
		TOTAL =	840.72

BINOCULAR ASSEMBLY (SM-D-657301)

Frame Assembly (SM-D-657337)	1		25.71
Light Emitting Diode Assy (SM-C-657443)	1		1.42
Ring, Retaining, Cres (MS-16632-4025)	1		.08
Connector, Plug, Elec (SM-D-657333)	1		3.20
Monocular Assy (SM-C-657305)	2		590.78
Ring, Diopter Adjust (SM-D-657334)	2		16.28
Washer, Lock, Cres No. 4 (MS-35338-135B)	4		.28
Screw, Machine - 4-40 (MS-51957-12B)	4		1.52
Ring, Lever (SM-C-657309)	2		5.52
Ring, Retainer (SM-C-657306)	2		.22
		TOTAL =	645.01

MASK ASSEMBLY, FACE (SM-D-657400)

Mask, Face (SM-D-657401)	1	75.54
Wire Harness (SM-D-657410)	1	16.57
Washer, Key (SM-C-657407)	1	.06
Knob, Rotary Switch (SM-C-657408)	1	3.58
Plate, Ident (SM-C-657409)	1	1.60
Screw, Machine (MS-51957-3B)	4	.92
Washer, Flat (MS-15795-802B)	4	.44
Washer, Lock (MS-35338-134B)	4	.20
Nut, Plain, Hex (MS-35649-134B)	4	.68
Case Assembly, Bat, (SM-D-657415)	1	10.23

Table 2-1. Weight Distribution in AN/PVS-5 Goggles (continued).

MASK ASSEMBLY, FACE (SM-D-657400)

	Quantity	Weight (grams)
Cap, Battery (SM-D-657404)	1	4.01
Gasket (SM-C-657405)	1	.43
Retainer (SM-C-657406)	1	.63
Screw, Machine (MS-51957-14B)	2	1.00
Washer, Flat (MS-5795-803B)	2	.22
Washer, Lock, No. 4 (MS-35338-135B)	2	.14
Nut, Plain, Hex (MS-35649-244B)	2	.96
	TOTAL =	117.21

KNOB ASSEMBLY (SM-B-657370)

Knob, Clamp (SM-B-657371)	1	3.10
Screw, Shouldered (SM-B-657372)	1	2.00
Nut, Self-locking, Hex (SM-B-657373)	1	1.40
	TOTAL =	6.50

FRAME ASSEMBLY (SM-D-657337)

Frame (SM-B-657338)	1	17.51
Link, Interpupillary (SM-C-657339)	1	1.25
Ring, Ring, Blk Passivated (MS-16633-4012)	1	.04
Guide, Assy (SM-C-657341)	1	3.88
Lever, Clamp (SM-C-657340)	1	1.93
Washer, Flat, Cres No. 5 (NAS-620C5L)	1	.05
SCR, Mach, Plan, HD-2-56 (MS-51957-1B)	1	.17
Washer, Lock Cres No. 8 (MS-35338-137)	2	.04
SCR, Mach-Pan HD-8-32 (MS-35218-38)	2	.84
	TOTAL =	25.71

Table 2-1. Weight Distribution in AN/PVS-5 Goggles (continued).

MONOCULAR ASSEMBLY (SM-C-657305)

	Quantity	Weight (grams)
Image Intensifier Assy (SM-D-657310)	1	121.75
Mount Assy, Objv Lens (SM-C-657375)	1	84.01
Nut, Retainer (SM-B-657335)	4	1.40
Washer, Lock, Cres No. 2 (MS-35338-134B)	4	.20
Lens Assy, Eyepiece (SM-C-657345)	1	81.15
Retainer, Eyepiece Adptr (SM-C-657308)	1	1.88
	TOTAL =	295.39

IMAGE INTENSIFIER, NIGHT VISION (SM-D-657310)

Housing, Tube (SM-D-657312) Pin, Link (SM-B-657313) Term, Stud (TYPE-SE-12XC01S)	1	25.80
Image Intensifier, Molded Assy (SM-C-657315)	1	95.95
	TOTAL =	121.75

MOUNT ASSEMBLY OBJECTIVE LENS (SM-C-657375)

Collar MTG Objv Lens (SM-C-657376)	1	11.60
Valve, Purge (SM-B-657398)	1	.28
Knob, Focus (SM-C-657377)	1	3.29
Retainer, Knob, Focus (SM-C-657378)	1	72.51
	TOTAL =	89.01

OBJECTIVE LENS ASSEMBLY (SM-B-657379)

CellAssembly Objv (SM-D-657380)	1	65.50
Sleeve, Objv Lens (SM-C-657396)	1	6.33
Retainer, Objective Lens (SM-B-657397)	1	.68
	TOTAL =	72.51

Table 2-1. Weight Distribution in AN/PVS-5 Goggles (continued).

LENS ASSEMBLY, EYEPIECE (SM-C-657345)

	Quantity	Weight (grams)
Lens and Sleeve Assembly (SM-B-657348)	1	65.28
Adapter Sleeve Assembly (SM-C-657366)	1	14.17
Pin, Guide (SM-B-657346)	3	.25
Elastomer (M-25988/3-128)	1	.98
Elastomer (M-25988/3-030)	1	.47
		TOTAL = 81.15

LENS AND SLEEVE ASSEMBLY (SM-B-657348)

	Quantity	Weight (grams)
Cell Assembly, Eyepiece (SM-D-657350)	1	53.16
Sleeve, Eyepiece Lens (SM-C-657349)	1	12.12
		TOTAL = 65.28

evaluation at NVL. It was recommended that the next experimental model should possess easier adjustments and a face mask with increased peripheral vision. These features were incorporated into the Mod I prototype and the goggles were again submitted for evaluation. As a result of the flight evaluation of this prototype, it was recommended that system resolution could be improved by fabricating high resolution image intensifier tubes. This modification was incorporated into the Mod II prototype.

2.1.1 Physical Description of Experimental Prototype Goggle

The experimental prototype goggle, shown in Figure 2-1, emphasized function rather than aesthetic appeal. The features which had the most influence on the design of the goggle were interpupillary distance, eye relief, diopter adjustment, and the location of the high voltage cables, connectors, and power pack. Critical consideration was also given to weight distribution and to the center of gravity of the goggles/helmet combination.

The goggle assembly consisted of a lightweight image intensifier tube, face mask, face cushion, tube housing,

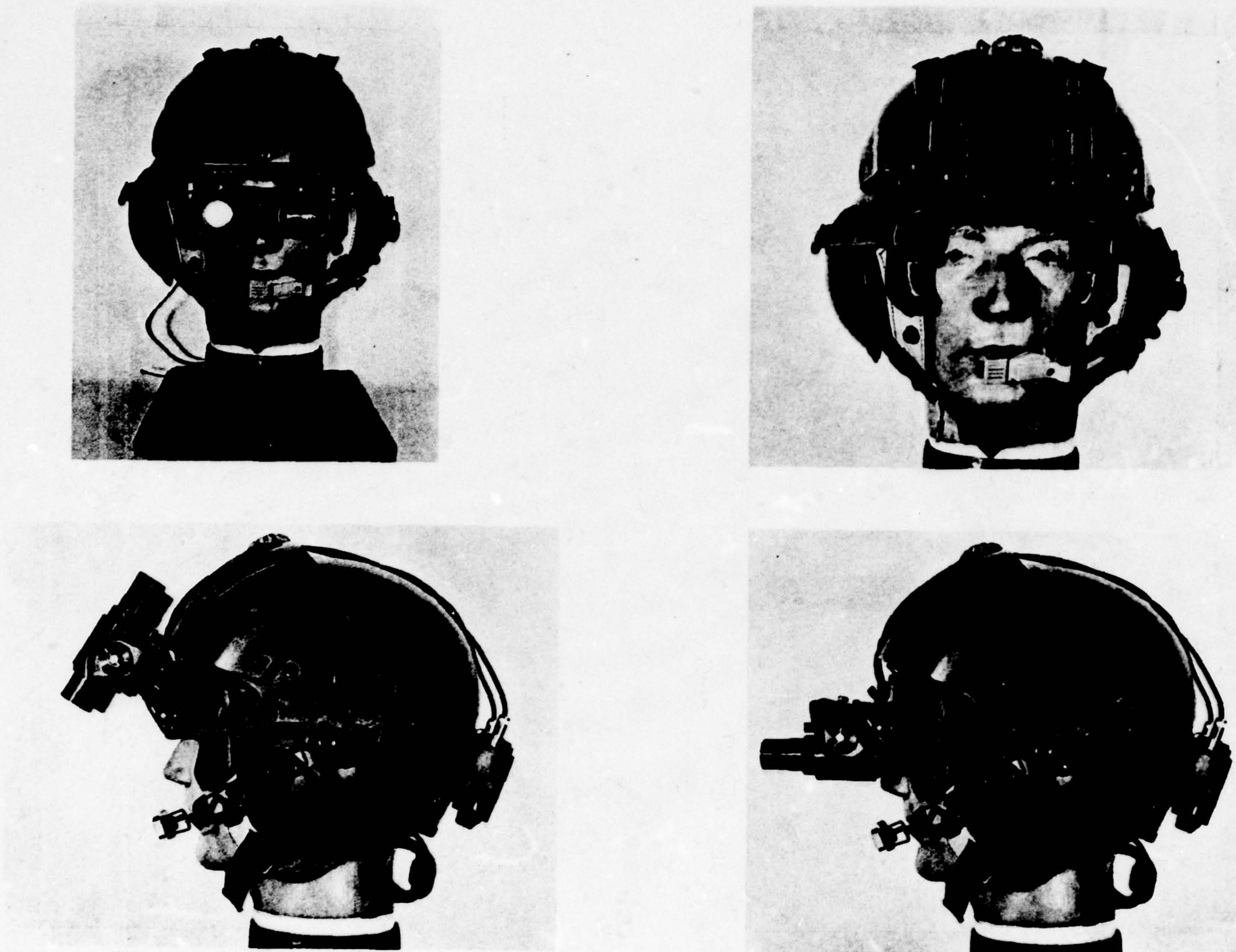

Figure 2-1. Experimental Aviation Goggles Attached to Flight Helmet.

objective lens assembly, eyepiece lens assembly, power pack, high voltage cables and connectors.

2.1.1.1 Construction

The experimental prototype goggle was constructed in the manner outlined in paragraphs 2.1.1.1.1 through 2.1.1.1.4.

2.1.1.1.1 Lightweight Image Intensifier Tube

Generation II microchannel wafer tubes were used in the experimental prototype goggle. Each tube had an output image diameter of 18 mm and possessed an S-20 photocathode with extended red response. The tube assembly used a microchannel electron multiplier plate with a proximity focus on both the input and output. The assembly contained an 0.060" glass window input faceplate and a fiber-optic inverter as an integral part of the tube.

2.1.1.1.2 Image Intensifier Tube Housing

The tube housings were made from Noryl-731® which is manufactured by General Electric Company. This material was chosen because of its outstanding dimensional stability in low temperatures and excellent mechanical and dielectric properties. Noryl-731® has easily passed all standard

thermal cycle tests, retains high impact strength down to $-53.9^{\circ}C$, and does not become brittle until $-169^{\circ}C$. In addition, it possesses a low heat deflection temperature of $+129.5^{\circ}C$. The material is also good for injection molding and forming and can be plated.

The housing itself was designed as a thin-walled cylinder in the following manner:

a. Image intensifier tube - In the AN/PVS-5 design, the image intensifier is potted into a plastic boot. Following this operation, the assembly is placed into a tube housing, collimated, and secured into position.

   In the aviation design, the tube housing itself was used as the plastic boot, which resulted in a savings in weight. Collimation was accomplished through the use of three adjustment screws located on the exterior of the tube housing. Not only did this design result in reduced weight, but the collimation could be completed in 1/6 of the time needed to collimate the AN/PVS-5.

b. Securing the objective lens to tube housing - In the standard AN/PVS-5 goggle, the objective lens is secured through the use of a mounting collar. In the aviation design, the tube housing accommodates the objective lens. This results in a savings in both weight and component parts.

c. Objective lens - The objective lenses used in the Aviation goggles were plastic and were modified for a glass cathode. The lenses were purchased from Eastman Kodak.

d. Objective lens sleeve - The objective lens sleeve was fabricated from Noryl-731®. The primary function of this sleeve was to seal the objective lens and tube housing from the environment. The use of this sleeve resulted in both a savings in weight and component parts. It takes five parts to accomplish the same task on the AN/PVS-5.

e. Eyepiece assembly - The eyepiece lenses used in the Aviation goggles were modified to accommodate the multistart threads needed for diopter adjustment. The lenses were procured from Eastman Kodak and were made of plastic.

f. Eyepiece adapter sleeve - The eyepiece adapter sleeve was fabricated from Noryl-731®. The function of this sleeve was to provide multistart threads for diopter adjustment and to act as an environmental seal between the eyepiece lens and the tube housing.

g. High voltage connector and cables - The connector housing was machined from corrosion resistant steel. The material used for the pin insulator was Teflon 100® which possesses a dielectric strength of $V/10^{-3}$in = 2100.

The high voltage cable contained 28 gauge, 7/36 stranded wire. The wire was rated for 60 volts and was made of Type E Teflon®. Shrinkable tubing, rated to 12 kV, was placed over the wires for greater protection. This configuration is shown in Figure 2-1.

h. Frame - The side frame was made of 6061-T6 AA aluminum. The inside of the frame (i.e., the side facing the goggle) was knurled to provide greater friction between surfaces. A self-clinching, self-locking fastener was pressed into the frame to allow the binocular assembly to be positioned and secured into place.

i. Frame rods - The frame rods were fabricated from 304 corrosion resistant steel. The rods were used to support the monocular assembly and to accommodate interpupillary adjustment.

j. Wing screw assembly - The wing screw assembly consisted of a washer and a nylon wing screw. The washer was knurled on one side to provide greater friction between the wing screw and the face mask. The smooth side of the washer was bonded to the nylon wing screw. The wing screw was used to adjust and lock the binocular assembly into the required position.

k. Face mask - The face mask consisted of two parts: a section which held the binocular assembly in the required position and a section which remained fixed to the face. The mask could be swung up, out of the viewer's line of sight, when it was not being used. The mask was made by a vacuum forming process using polyphenylene oxide, Mod Class 2, in accordance with MIL-R-46129. The mask was a nominal thickness of .125". To hold the goggles in either the up or down position, a spring loaded hinge was used.

l. Face cushion assembly - The face cushion was made from surgical foam. The cushion was backed with a Velcro® loop fastener. Both the cushion and Velcro® fastener were fabricated by stamping.

m. Power pack - the power pack was made by the vacuum forming process using polyphenlene oxide, Mod Class 2, in accordance with MIL-R-46129. The nominal thickness of the power pack was 0.04". The power pack contained the following items:

(1) Battery - 9 Vdc
(2) Switch - on/off
(3) High voltage connectors
(4) Power supply
(5) Power adapter
(6) 28-Vdc cable

n. Power supply - The power supply was particularly designed for use in the Aviation goggles. The supply provided power to both image intensifier tubes. The single unit possessed automatic brightness control (ABC), bright source protection (BSP), and operated on 9 Vdc.

o. Power adapter - The power adapter converted 28-Vdc aircraft power to 9 Vdc which, in turn, supplied the goggles. The power adapter contained a switching device to convert the goggle to battery power, in case the aircraft power failed.

p. 28-Vdc cable - One end of the 28-Vdc cable was mated to the 28-Vdc aircraft power connector. The other end of this cable was attached to the power pack housing. The cable was constructed in accordance with MIL-C-27500. The two component wires were Type E24, 19 strand, 24 AWG, in accordance with MIL-W-16878/4. The wires were covered with a tinned, annealed, copper braided shield and a jacket of braided lacquered nylon. The housing for the connectors, which were attached to the 28-Vdc cable, were machined from Noryl-731®. The connector housing encloses the high voltage receptacle and plug, both of which are spark retardant.

2.1.1.1.3 Weight of Experimental Prototype Goggle

The weight of the experimental prototype goggle assembly was 696.7 grams (less head straps). The weight breakdown is shown in Table 2-2.

Table 2-2. Weight Breakdown for Experimental Prototype Aviation Goggles.

	Quantity		Weight (grams)
Binocular Assy	1		255.27
Mask Assy Face	1		103.40
Cushion Assy	1		30.00
Knob Assy	2		3.77
Power Pack Assy	1		256.70
Battery	1		47.56
		TOTAL =	696.70
KNOB ASSEMBLY			
Washer	1		.90
Wing Screw	1		.98
		TOTAL =	1.88
MASK ASSEMBLY FACE			
Mask Face	1		85.90
Hinges and Spring	2		10.18
Screws, Machine	12		2.94
Washer, Flat	12		1.56
Washer, Lock	12		.60
Nut, Plain, Hex	12		2.22
		TOTAL =	103.40
BINOCULAR ASSEMBLY			
Frame Assembly	1		11.00
Monocular Assembly	2		244.27
		TOTAL =	255.27
FRAME ASSEMBLY			
Frame Rods	2		3.56
Nuts	4		.73
Washer	4		.41
Self Clinching Fastener	2		1.82
Side Frame	2		4.18
Set Screws	4		.30
		TOTAL =	11.00

Table 2-2. Weight Breakdown for Experimental Prototype Aviation Goggles (continued).

	Quantity	Weight (grams)
MONOCULAR ASSEMBLY		
Image Intensifier (glass cathode)	1	45.53
Potting	1	7.08
Housing, Tube	1	11.66
Eyepiece Assy	1	26.13
Eyepiece Adapter	1	4.31
"O" Ring	1	.45
"O" Ring	1	.28
Objective Assy	1	23.30
"O" Ring	1	.28
Lens-Collar	1	4.00
"O" Ring	1	.28
		TOTAL = 123.30
POWER PACK ASSEMBLY		
Power Pack	1	20.00
Power Pack Cover	1	9.34
Screw	6	3.00
Washer	6	.66
Lockwasher	6	.42
Power Supply	1	43.19
Power Adapter	1	20.27
Connector S. H. V.	2	39.57
28-Vdc Cables	1	56.31
Switch	1	11.00
Potting	-	53.19
		TOTAL = 256.70

2.1.1.1.4 Center of Gravity of Experimental Prototype Goggle

The following method was used to determine the center of gravity of the SPH-4 flight helmet with the Aviation goggles attached:

a. The SPH-4 flight helmet was mounted on a dummy head.

b. Lines were fixed to the ceiling and the flight helmet was attached. The lines were adjusted until the center of gravity was found.

c. With the unit still suspended, the goggles were attached to the unit and the new center of gravity was determined.

It was determined that the center of gravity did not change when the experimental prototype goggles were added to the SPH-4 flight helmet, i.e., the moment equalled zero.

2.1.2 Physical Description of the Mod I Aviation Goggles

As a result of the recommendations made by NVL, the experimental prototype Aviation goggle was modified in the following manner:

a. Face mask - Both sections of the face mask were modified to increase its length. In addition, material was removed from the sides of the mask to increase the user's peripheral vision

b. Power pack - The length of the power pack was increased to allow easier removal of the battery. This was accomplished by reworking the mold.

c. Tube housing - The tube housing was redesigned to provide a lock-down capability for interpupillary adjustment in the horizontal position.

d. Adapter sleeve eyepiece - The adapter sleeve eyepiece was modified by adding a fine pitch thread over the existing multiple threads. In addition, a stop was added to prevent the eyepiece lens assembly from disengaging when maximum diopter travel was reached.

e. Thumb screws - Thumb screws were added to the goggle system for better interpupillary adjustment locking.

f. High voltage connectors - The high voltage connectors were eliminated to save weight. Interface with the power supply was made with pin connectors to permit easier installation. All other connections were soldered to ensure a permanent coupling.

g. Face mask locking device - The device was modified to eliminate the spring on the hinge. It was replaced with a strike and catch mechanism which allowed the goggle to be locked into the down position. In the up position, the face mask was secured by means of a tab of Velcro® (hook) material. The tab was placed on the end of the mask. The Avionics "V" strap (AN/PVS-5) was modified with Velcro® (loop) material to complete the fastener.

2.1.2.1 Weight of Mod I Goggle

The weight of the Mod I experimental prototype Aviation goggle was:

Weight of face mask assy	= 383.8 g
Weight of power pack	= 256.7
Total weight	= 640.5 g

2.1.2.2 Center of Gravity of Mod I Goggle

The center of gravity of the Mod I goggle did not change, i.e., the moment equalled zero.

2.1.3 Physical Description of the Mod II Aviation Goggle

The existing image intensifier tubes were replaced with Generation II, high performance tubes. The tubes employed S-20 photocathodes with extended red responses, electron-multiplier plates with proximity focus on the input and output, and an RCA F2126, Type 10-52 phosphor screen. The assembly contained a fiber-optic input faceplate and a fiber-optic inverter as an integral part of each tube envelope.

The goggles were modified in two different configurations. One set of goggles retained the external power supply, while the second set utilized individual donut power supplies which were wrapped around the image intensifier tubes.

2.1.3.1 External Power Supply Configuration

In the external power supply configuration, the following modifications were incorporated:

a. Tube housing - The tube housing was redesigned to permit an increase in the intensifier tube length.

b. Face mask locking device - The locking mechanism was redesigned to provide more positive locking action. The section of the mask which pivots upward was provided with a blade-like device which, when passed through a "U" channel, secured the unit into position by means of a spring plunger. The amount of force required to snap the mask into position was adjustable. The mask was locked into the down position in a similar manner.

c. Diopter adjusting levers - Diopter adjustment levers were installed on the eyepiece assembly to provide a better grip for the user's fingers. The levers were machined from AA Al 6061-T6.

2.1.3.1.1 Weight of Mod II External Power Supply Configuration

The weight of the Mod II experimental prototype goggle in the external power supply configuration was:

Weight of face mask	=	469.00 g
Weight of power pack	=	214.50
Total weight	=	683.50 g

2.1.3.1.2 Center of Gravity of Mod II External Power Supply Configuration

The center of gravity of the configuration did not change, i.e., the moment equalled zero.

2.1.3.2 Wraparound Power Supply Configuration

In the wraparound power supply configuration, the following modifications were incorporated:

a. Tube housing - The tube housing was redesigned to permit an increase in intensifier tube length. In addition, the interpupillary locking screw was changed to an inclined position to provide a better grip for the user's fingers.

b. High voltage cables - The high voltage cables were redesigned because the maximum voltage was reduced to 2.7 Vdc. The cables were 7/38 stranded wire with TFE Teflon® insulation. The wires were further protected by a single silver plated shield and an extruded Teflon® outer jacket. The cable also possessed a special steel core wire with an outer layer of silver plated copper. The inner steel core provides extra strength, while the outer copper layer provides greater carrying capacity at high frequencies.

   Microminiature connectors were used on the power pack connection end of the cables. The other end of the cable was permanently soldered to the tube.

c. Power pack - The power pack was redesigned to enclose only the 28-Vdc power adapter, ON and OFF switch, and battery compartment for the 2.7-Vdc battery. The power pack compartment was machined from Noryl-731® and possessed the following dimensions: 2.25" high X 2.06" wide X 1.60" deep. Microminiature connectors were mounted to the power pack to provide tube power and a connection to the 28-Vdc power adapter.

d. 28-Vdc breakaway cable - The 28-Vdc breakaway cable was replaced by a microminiature cable. A microminiature connector was placed on the end of the cable which connected to the power pack.

e. Face mask locking device - The locking device was changed in the same manner as indicated in 2.1.3.1.b.

f. Diopter adjustment levers - The diopter adjustment levers were changed in the same manner as indicated in 2.1.3.1.c.

2.1.3.2.1 Weight of Mod II Donut Power Supply Configuration

The weight of the Mod II experimental prototype goggle in the donut power supply configuration was:

Weight of face mask	=	461.56 g
Weight of power pack	=	192.93
Total weight	=	654.49 g

2.1.3.2.2 Center of Gravity of Mod II Donut Power Supply Configuration

The center of gravity of the donut power supply configuration changed from a moment of zero to a moment of 0.734 nm.

3.0 CONCLUSION

In this development effort, it was shown that it was feasible to develop an external power supply, high voltage cables and high voltage connectors which did not degrade the performance of the goggles. This method of design led to a counterbalance on the pilot's helmet inturn providing zero moment, which reduces fatigue. Some of the pilot's comments about the counterbalance are as follows:

a. After 2.0 hours of flip-up wear, he felt very little fatigue and could have flown another hour before arriving at the same fatigue level experienced with the old type goggle design. The weight and its distribution are definite assets in nap-of-the-earth (NOE) flight in closely confined areas. The light weight permits the pilot's head to rotate, checking for obstacles as freely as he is able to during normal daylight NOE flight

b. The pilot wore the goggles and helmet for the next four hours. The helmet and goggles were worn during a 30-minute refueling stop, which occurred after the first two hours of flight. No ill effects were suffered by the subject pilot during the four hours. The fatigue felt by the pilot was on par with the amount of fatigue that would have been felt by the pilot after four hours of daylight NOE flight. It is the opinion of this pilot that the flip-up design goggles could be safely worn in flight by a pilot for a period of four hours NOE in a peacetime situation and up to six or eight hours in a wartime situation, since the pilot's endurance level increases through use

In the design of the face mask, many comments were made about the openness and the fact that the pilot had to have a lighttight system. The following are some of the comments the pilots have made about the openness design:

> The most outstanding feature of the modified flip-up goggles was discovered during a map reading exercise on the test. When asked to utilize his map to navigate from point A (the IP.) to point B (the confidence course RP) by the most direct flight path, the subject pilot discovered he could read the map by looking under the goggle tubes. There was no need to flip the tubes up to see the map. The subject pilot was able to utilize his aircraft map light to illuminate the map, cover the light and immediately look out through the goggle tubes to check terrain references depicted on the map. He was also able to illuminate and read the aircraft instruments and compass without flipping up the tubes by looking underneath the tubes and placing the map light very close to the desired aircraft instrument. This ability to check magnetic heading, airspeed, altitude, temperature and pressure instruments without flipping up the goggle tubes is outstanding. It permits the aviator to manage the aircraft as copilot exactly as he would during daylight NOE flight; it also gives him the ability to take control of the aircraft and fly it without any delay that might be caused by flipping the tubes down. It should also be noted that the level of light used to read the map and aircraft instruments did not adversely affect the safety pilot, who was utilizing a standard set of goggles.

On the subject of flip-up face mask vs a fixed mask, one of the pilots had the following experience:

A problem occurred on the first goggle approach into the DZ. On approach, one helicopter was spotted hovering on the landing strip. After initiating a go-around, another helicopter was spotted. It was converging on the mission aircraft from the center of the DZ approximately one-half mile away. The subject pilot was able to flip up the avionics goggles and turn on all instruments, navigation and anticollision lights prior to the safety pilot's getting his standard goggles off. It should be noted that the subject was at the controls and accomplished all these tasks while continuing to fly the aircraft. This would not have been possible utilizing the standard goggle design and a midair collision might have occurred.

The present Aviation Goggle design, either internal or external power supplies configurations, does meet the pilots' requirements for lightness balance, openness, and performance; however, further work should be started in developing a new set of Aviation Goggles. We now know what the pilot requirements are, and alot of the groundwork has been completed; for example:

- o Total weight to be 454 grams
- o Gen III tubes or high performance Gen II tubes
- o Plastic optics
- o Peripheral vision-sides, top, bottom and front views
- o Flip-up and shut-off goggle system
- o Goggles to shear off in case of a crash

In summary, in this development effort the use of an open type face mask which allowed the pilot some peripheral vision was very desirable. This type of mask allowed the pilot to view maps and to pursue other activities within the cockpit without flipping the goggles totally out of his line of sight. In addition, it was determined that weight and moment were critical factors from the user's standpoint. The following is a comparison of the mechanical advantages of the Aviation Goggle developed under NVL guidance as opposed to the standard AN/PVS-5A Night Vision Goggle.

Parameter	AN/PVS-5A	Aviation Goggle (with Donut P.S.)
Total system weight	840.72 g	654.49 g
Face mask assy	195.71 g	133.96 g
Binocular assy	645.01 g	327.60 g
Total sys moment	1.7 nm	0.734 nm
Type face mask	closed	open
Type emergency action	removal	quick flip-up and lock
Aircraft power supply adapter	-	included in power pack 192.93 g